Applying Structured Scaffolding for Enhancing Problem Solving for Underrepresented Minorities in STEM Disciplines

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Abstract

Many underrepresented STEM students struggle in college because of their deficiencies in problem solving. This is primarily due to the students' lack of conceptual understanding and inability to apply their mathematical knowledge while solving engineering problems. In addition, in most STEM programs, problem solving is not separately taught as a topic or course. It is rather assumed that problem solving ability is expected to naturally increase by mastering domain concepts as well as mastering relevant problem solving heuristics and processes, and ultimately learning to put these concepts and processes together to solve problems. Our research suggests that, for underrepresented minority students, learning conceptual knowledge can be best achieved through practicing problem solving in a gradual learning approach supported by scaffolding techniques.

The paper describes a teaching strategy for problem solving utilizing mini-projects as supplemental instruction in any engineering mechanics course, such as "statics" or "strength of materials." This project-based instruction focuses on the analysis of a mechanical system consisting of multiple springs and pulleys. Students were assigned one system configuration and were required to identify relevant concepts, formulate mathematical relationships, derive the system's governing equations and solve for the required variables. The derivation of mathematical equations was conducted for the assigned system involving physical parameters with appropriate assumptions and constraints. In addition, laboratory experimental models were built to offer students additional scaffolds to help understand the concepts which led to increasing their ability to solve the problem. The physical models also enabled adjusting or changing the system's parameters and/or configurations.

Although the mathematical content and physical concepts required for the project are fairly simple, some difficulties for the "novice" student exist for developing, organizing and solving the system's linear equations. For the "expert" students, the problem can be made more challenging by increasing the number of system components or by assuming spring stiffnesses to be different (k_1, k_2, etc.) instead of having same value (k). For the struggling students, the original system configuration was simplified into sub-systems to facilitate a scaffolding instructional technique. Students were guided to first work out a simpler system with fewer springs and thus fewer unknown variables. During this scaffolded activity, students established their basic skills in formulating the mathematical model, applying the engineering concepts (such as Hooke's law, pulley concept and free-body diagram, etc.), and drafting the solution plan to obtain the final results. During all project stages, instructional soft scaffolds were offered by the instructor. By gradually increasing the system complexity, students enhanced their conceptual understanding, mathematical manipulation skills as well as problem solving competency. During the student's growth in knowledge and skills, the instructor's scaffolding was gradually reduced and ultimately removed.

An assessment instrument for problem solving was designed and utilized to evaluate the effectiveness of the students' learning. Research results showed positive students' feedback and notable progress in project engagement as well as improvement of their overall knowledge and skills.

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